

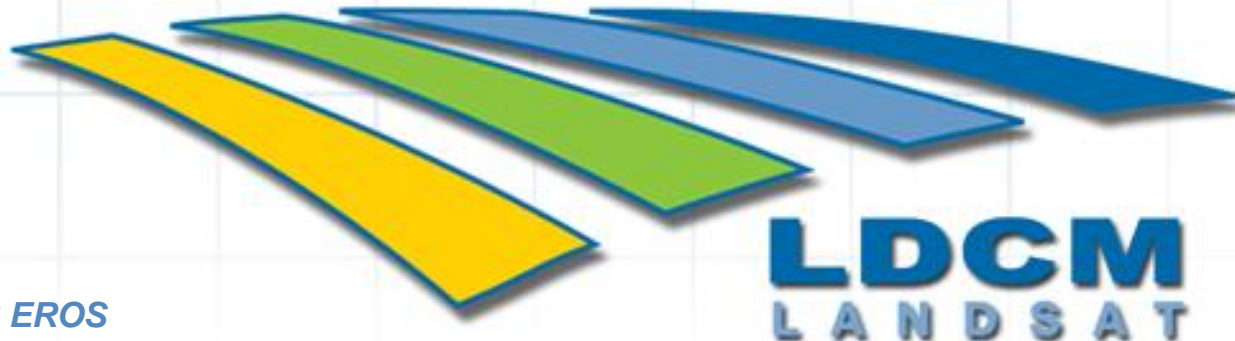


National Aeronautics and Space Administration



# The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance

**Brian L. Markham, NASA/Goddard Space Flight Center,  
Edward J. Knight, Brent Canova, Eric Donley, Geir Kvaran, and  
Kenton Lee  
Ball Aerospace & Technologies Corp.**



data continuity mission

**NASA GSFC / USGS EROS**

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# OLI Presentations



- **The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance Characterization --- Brian Markham—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee — Ball Aerospace & Technologies Corp.**
- **Operational Land Imager: Radiometric Calibration Overview --- Geir Kvaran — Ball Aerospace & Technologies Corp.**
- **Reflectance Factor Measurements of the OLI Flight Diffusers --- Stuart Biggar, Nikolaus Anderson—University of Arizona; Linda Fulton, Geir Kvaran, Harlan Kortmeyer—Ball Aerospace & Technologies Corp.**
- **The OLI Radiometric Scale Realization Round Robin Measurement Campaign -- Hansford Cutlip, Jerold Cole—Ball Aerospace & Technologies Corp.; B. Carol Johnson, Stephen Maxwell—NIST; Milton Hom, Brian Markham, Lawrence Ong—NASA Goddard Space Flight Center; Stuart Biggar—University of Arizona, College of Optical Sciences**



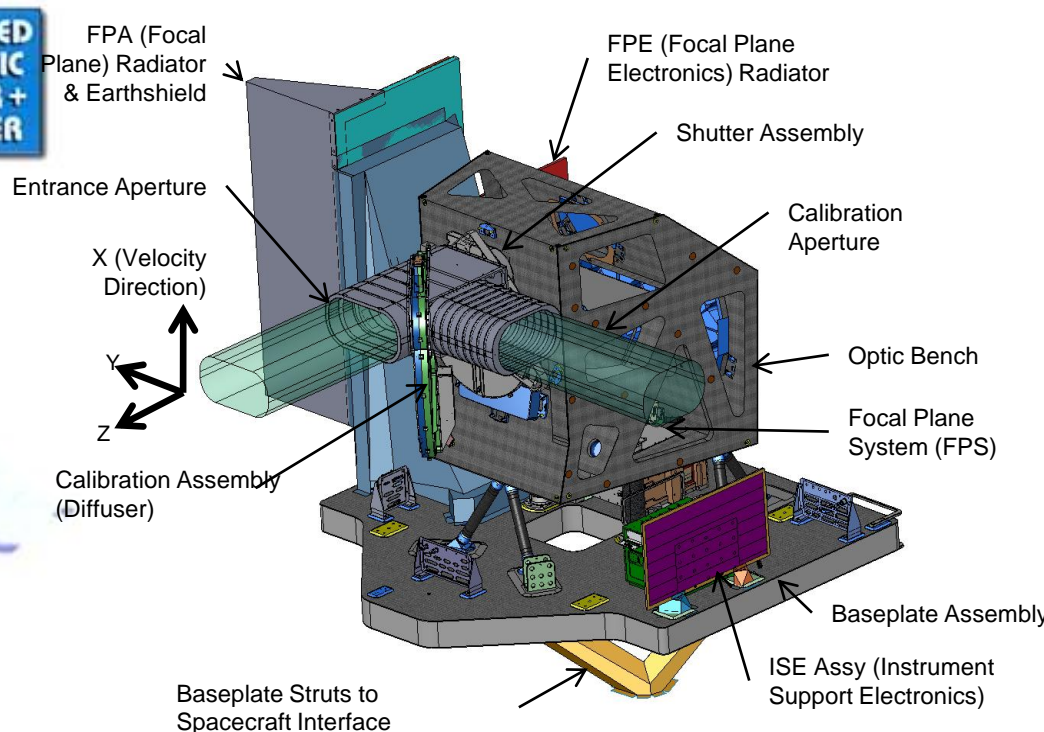
# Outline



- Instrument Description Overview
- Summary of Testing
- Summary of Test Results



# The Operational Land Imager (OLI) represents a generational change in Landsat technology



- Whiskbroom imager
- Obscured telescope
- 1020 cm<sup>2</sup> aperture
- 8 bits transmitted to ground
- VIS/SWIR and IR

- Pushbroom Imager
- Unobscured telescope
- 143 cm<sup>2</sup> aperture
- 12 bits transmitted to ground
- OLI is VIS/SWIR only (TIRS does IR)

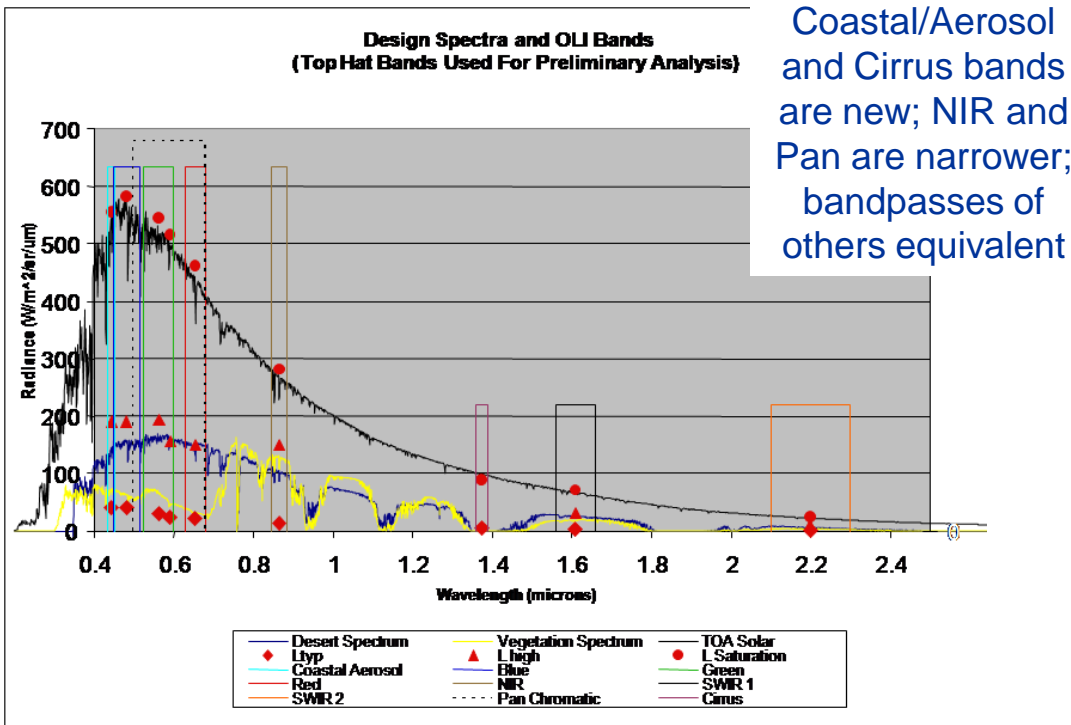


# OLI Maintains Landsat Legacy



## ■ Landsat Continuity Mission demands

- Accurate spectral and spatial information
- Frequent synoptic earth views
- NIST calibrated over time
- Precise geo-referenced data



## ■ Key instrument parameters

- Cross-track FOV 185 km
- S/C altitude 705 km
- Geodetic accuracy\*
  - ❖ Absolute 65 m
  - ❖ Relative 25 m
- Geometric accuracy\*\*
  - ❖ Absolute 12 m

Band Name	CW (nm)	Bandwidth (nm)	GSD (m)	SNR
Coastal/Aerosol	443	20	30	130
Blue	482	65	30	130
Green	562	75	30	100
Red	655	50	30	90
NIR	865	40	30	90
SWIR 1	1610	100	30	100
SWIR 2	2200	200	30	100
PAN	590	180	15	80
Cirrus	1375	30	30	50

Visible/NIR SWIR

\*No terrain compensation

\*\*w/ terrain compensation

Note: Geometric reqts are tighter for OLI

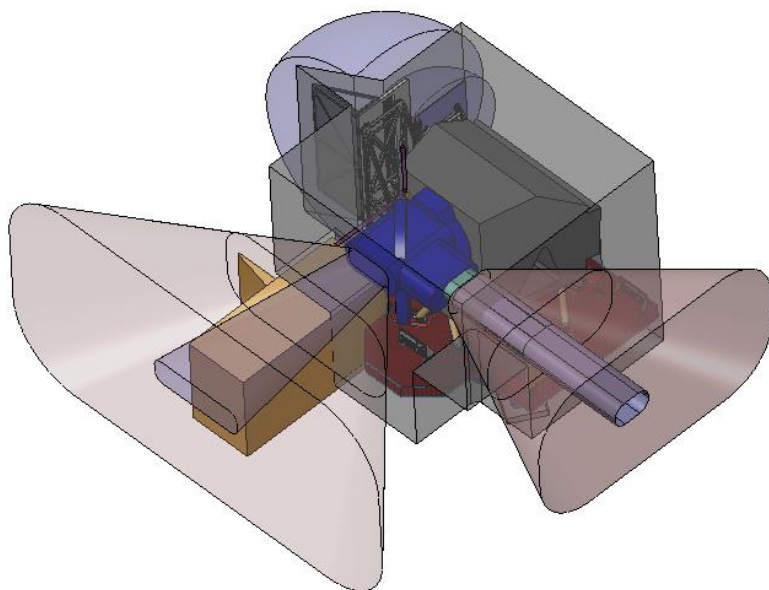
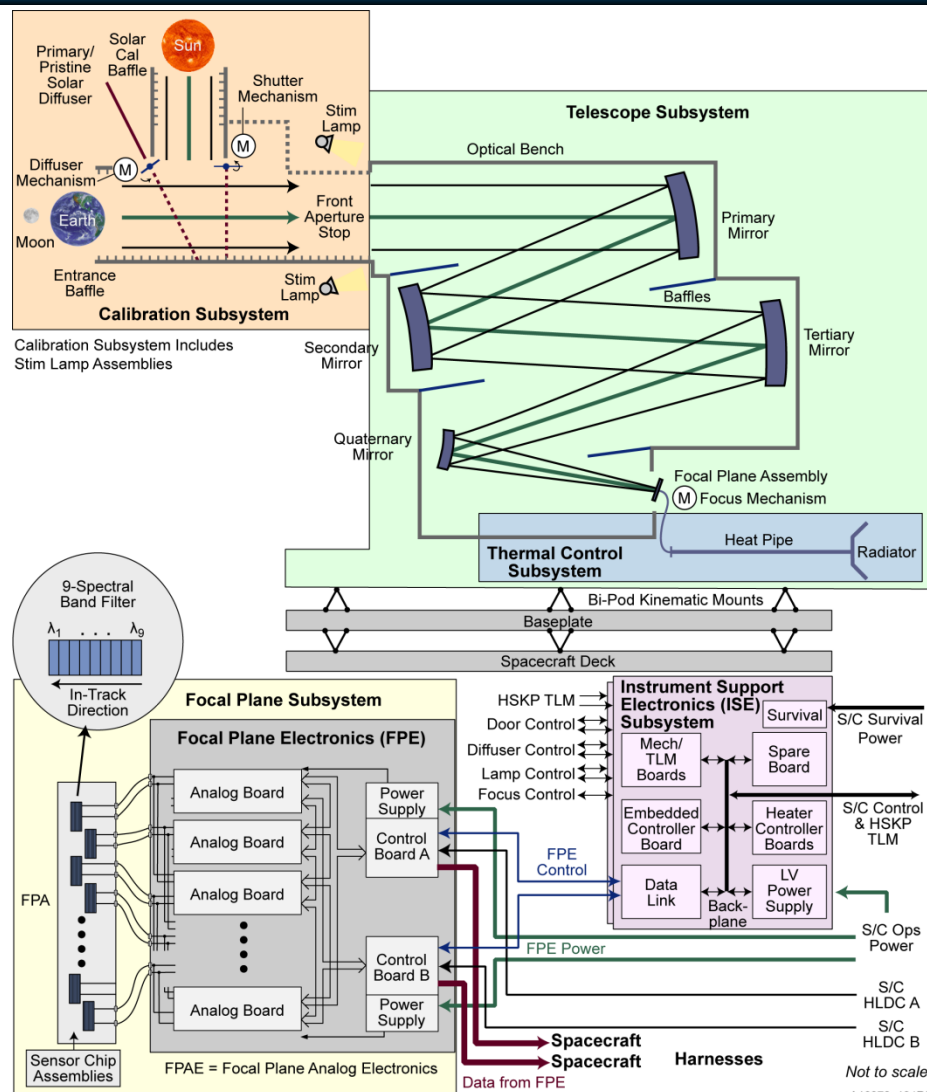




# OLI is a fairly simple instrument



- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- On-board calibration with both lamps and full aperture diffusers

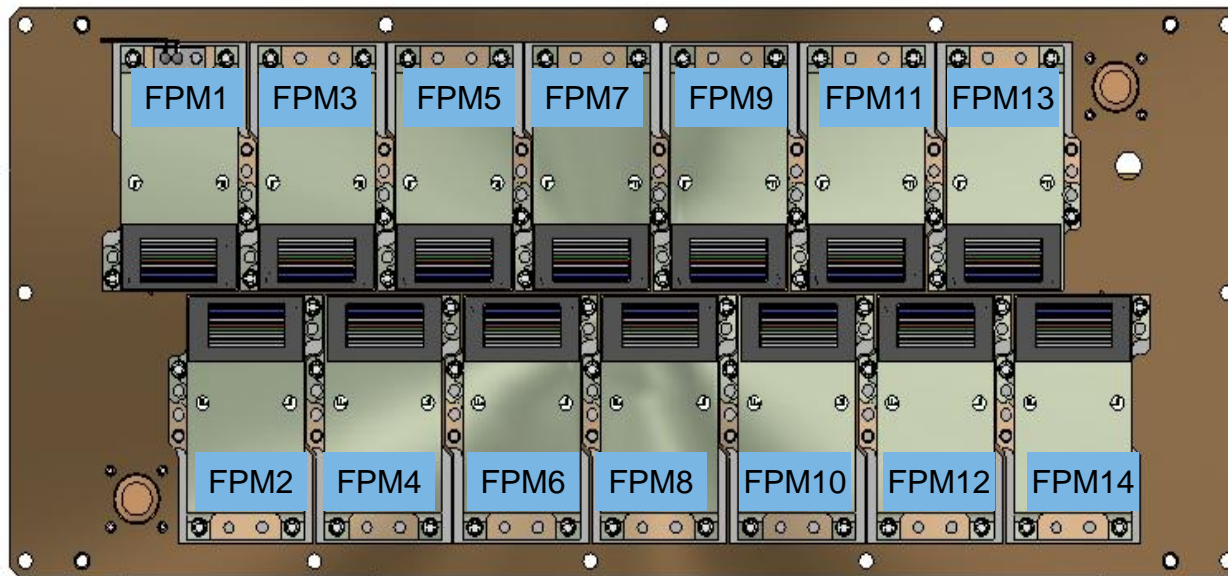




# OLI Focal Plane



- **Focal Plane Array**
  - Consists of 14 modules to cover the 15-degree field of view
  - 6919 detectors per multi-spectral band (13832 for Pan band)
- **Focal Plane Module (FPM)**
  - 494-detector array for each multi-spectral band (988 for Pan band)
  - Silicon PIN detectors for VNIR bands, HgCdTe detectors for SWIR bands
  - Butcher-block filter assemblies cover the detector arrays





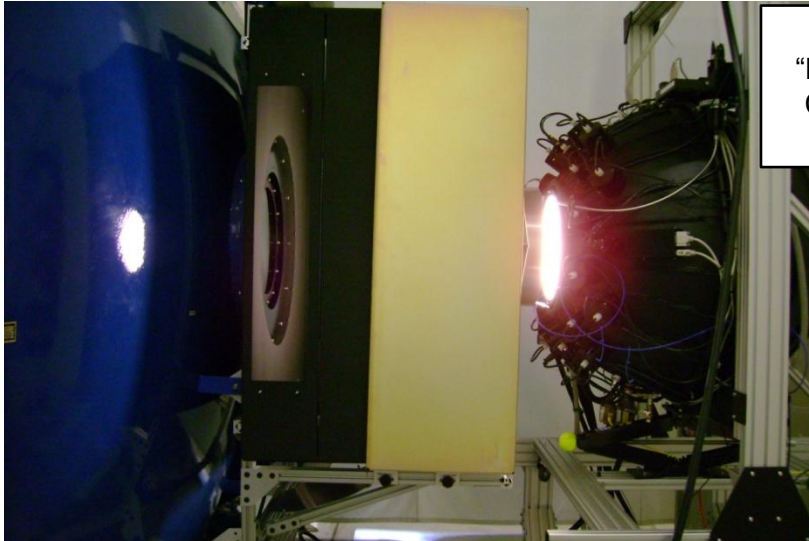
# OLI Is Complete\*







# Radiometric and Spectral Tests Completed with traditional spheres and monochromators



Aligning  
"Death Star"  
Calibration  
Sphere

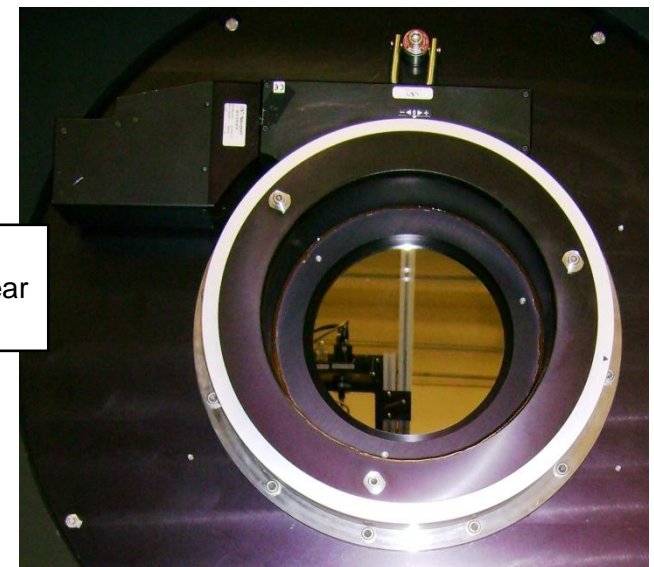


Inspecting  
heliostat  
alignment

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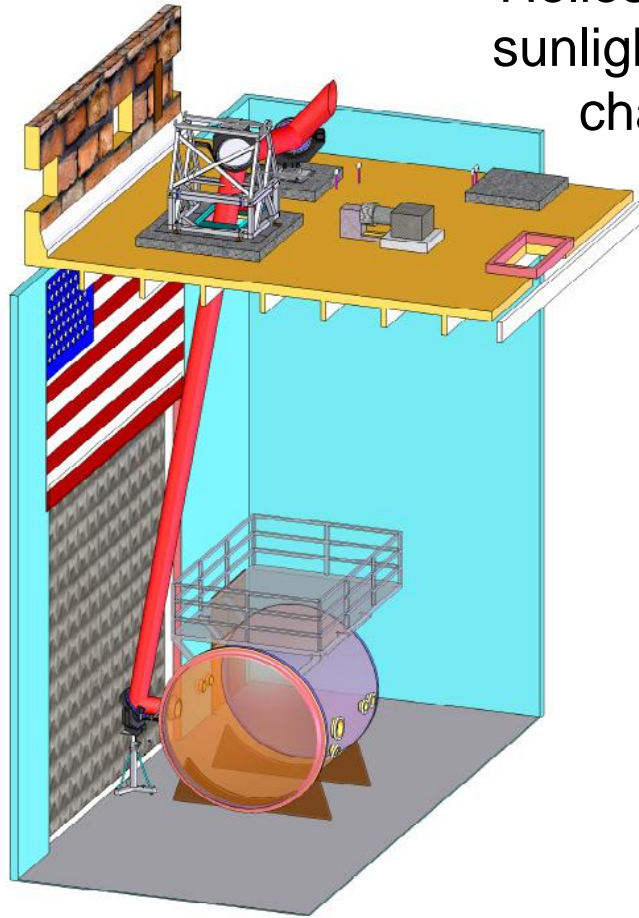
Spectral  
Measurement  
Assembly



Large  
aperture linear  
polarizer



# Heliostat Calibration provides transfer of calibration to orbit

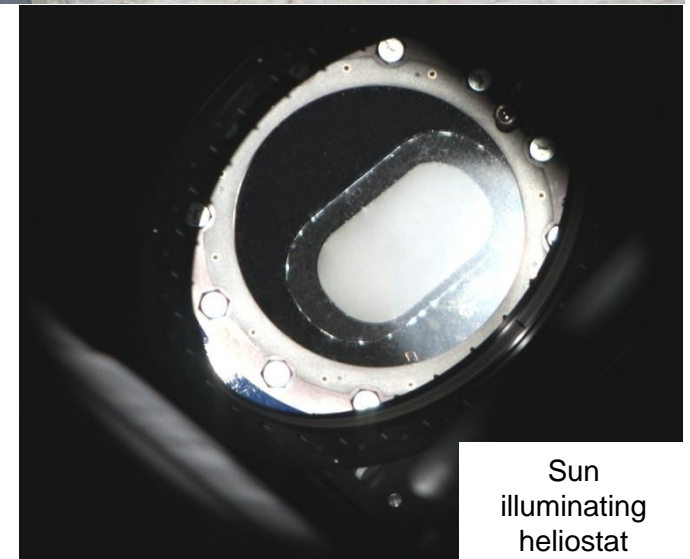


Heliostat steers  
sunlight into T/V  
chamber

Atmospheric  
transmittance  
characterized by  
University of  
Arizona



Measuring  
Heliostat  
Transmission



Sun  
illuminating  
heliostat



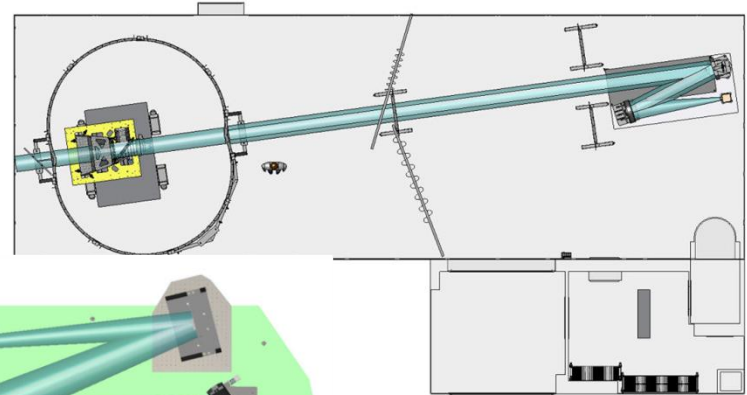


# Extensive Spatial Characterization



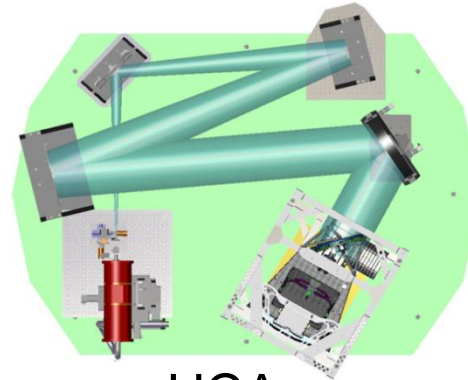
- Conducted stray light characterizations in state of art facility

Stray light facility



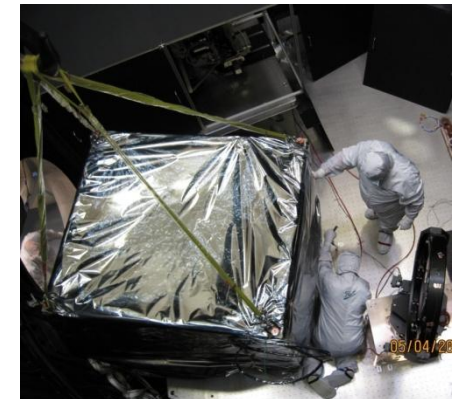
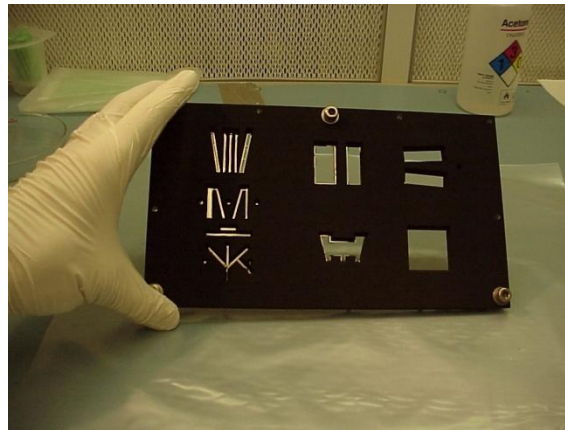
- Other Spatial Characterizations with BATC's Horizontal Collimator Assembly (HCA)

- Collimator and instrument in Vacuum
- Various spatial targets used to conduct characterizations of edge response, ghosting, bright target recovery, pointing



HCA

Spatial targets used for testing



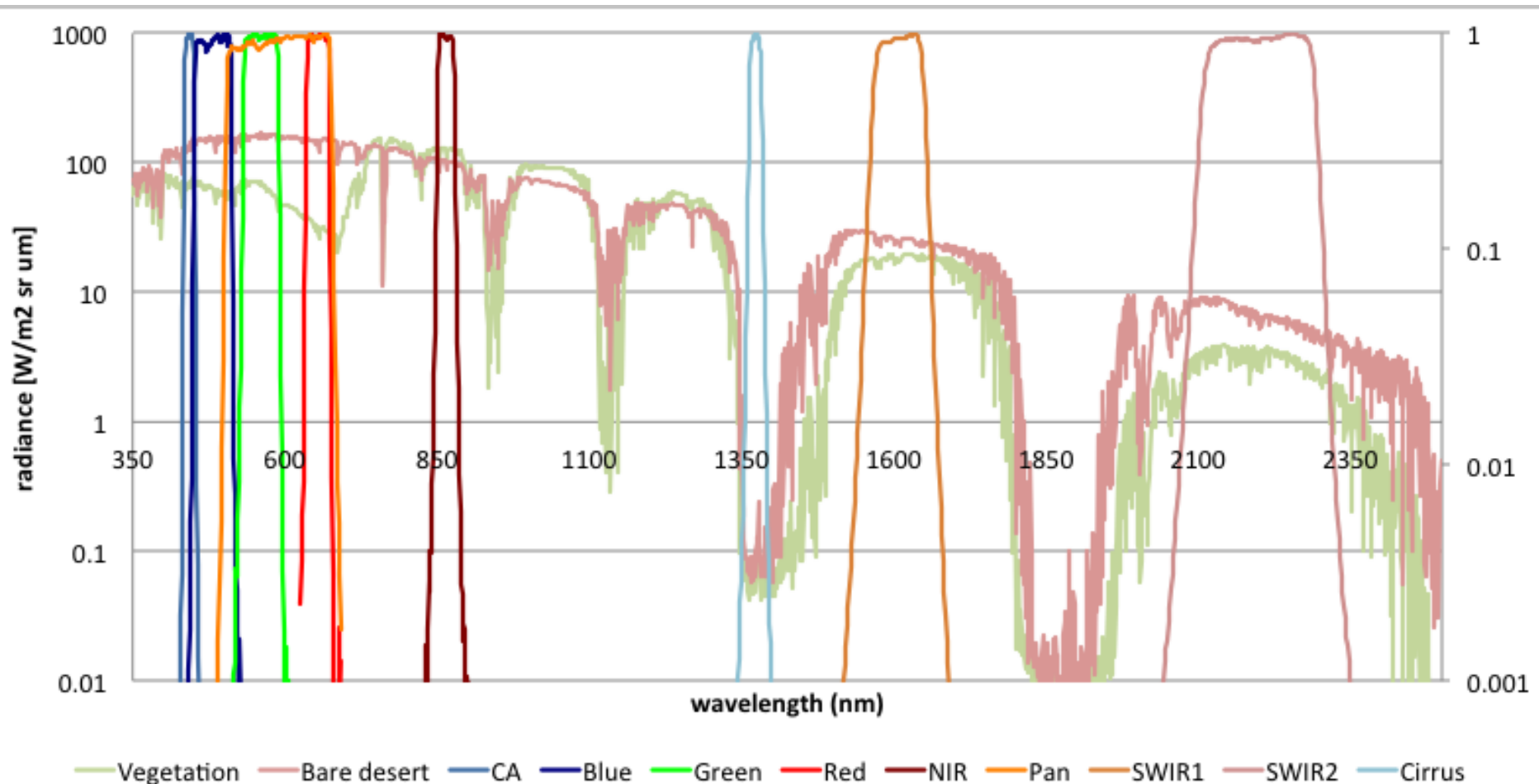
OLI being lowered into chamber for spatial testing



# Spectral Performance - In band



- Relative Spectral Responses have desired sharp bandpasses







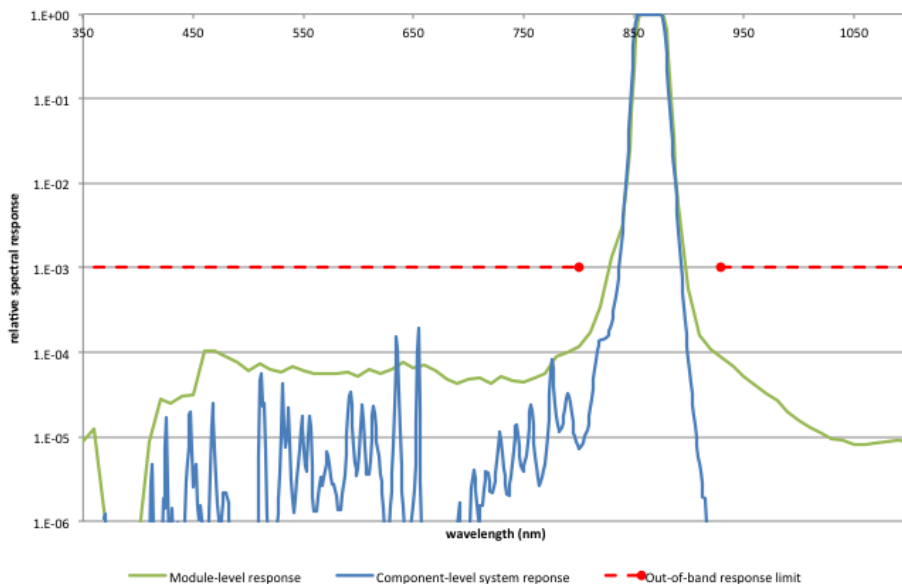
# Spectral Performance – Out-of-band



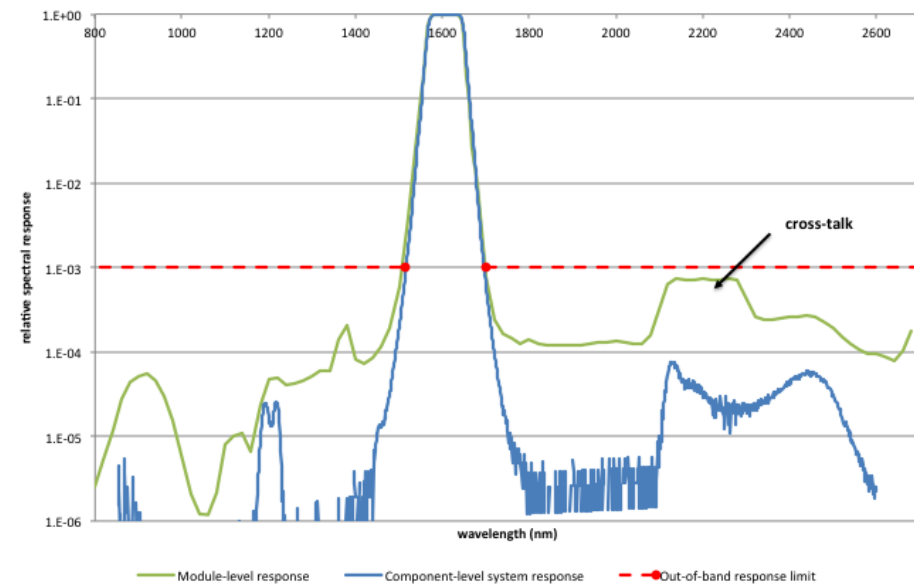
## ■ Out-of-band response

- Measured at Focal Plane Module (Detectors + filters) level; focal plane fully illuminated; optics contribution (mirrors + window) analytically added
- Typically  $10^{-4}$  or better (approximate stray light level in test set up)
- Some SWIR band crosstalk – most likely within detector *material*—within requirements

NIR FPM09 Out-of-Band Relative Spectral Response



SWIR1 FPM09 Out-of-Band Relative Spectral Response



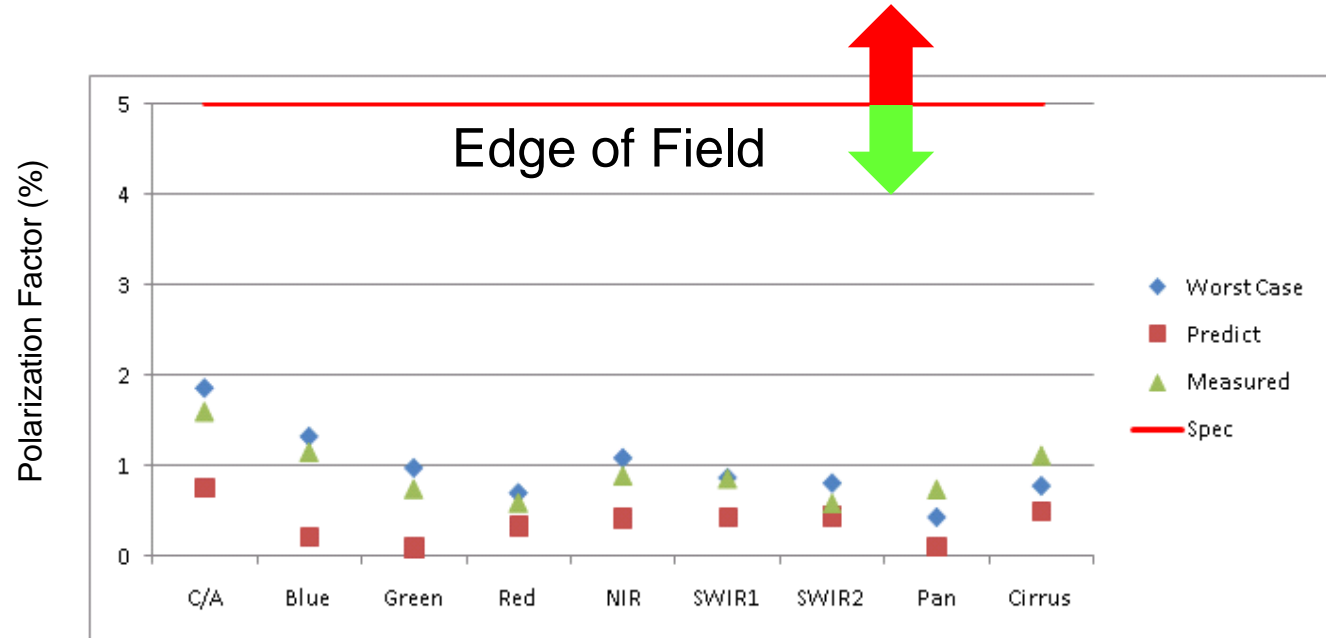


# Polarization Performance



## ■ Polarization

- Polarization Sensitivity well below 2%
- Will not alter measured signal from highly polarized scenes such as canopies and water





# Radiometric Performance

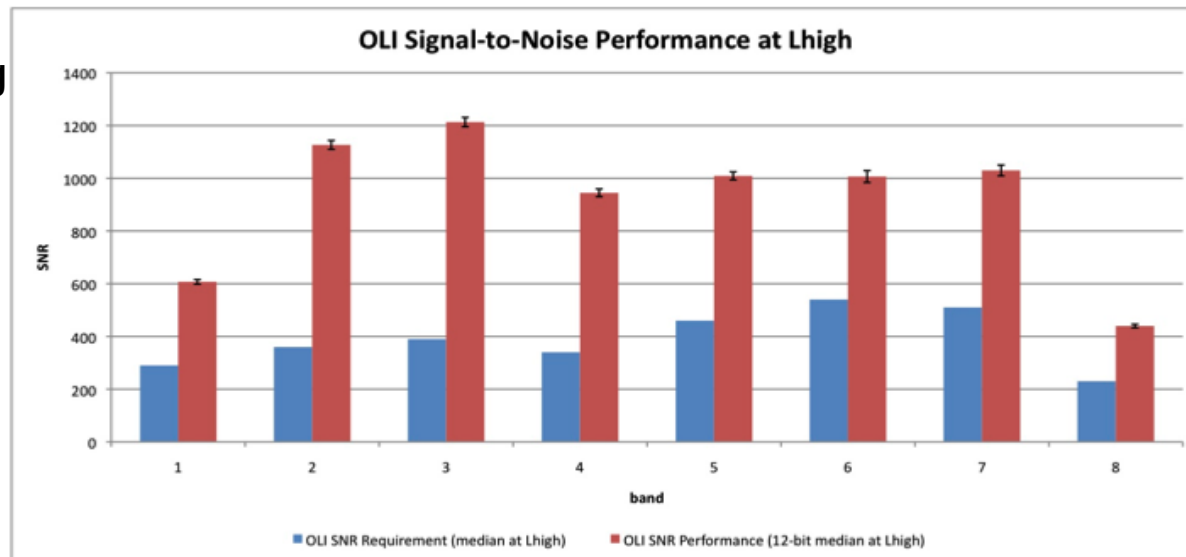
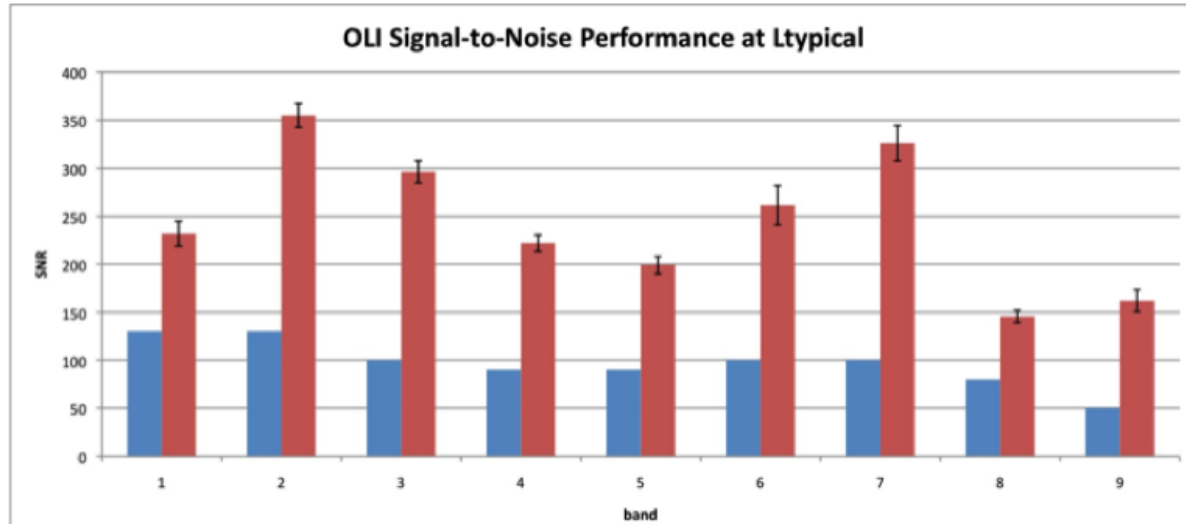


## ■ SNR

- SNR significantly exceeds requirements and heritage

## ■ Calibration

- Radiance uncertainty ~3.5%
  - ❖ Extensive round robin for NIST traceability
  - ❖ Transfer-to-Orbit uncertainties measured
- Reflectance uncertainty ~2.5%
- To be discussed in upcoming presentations

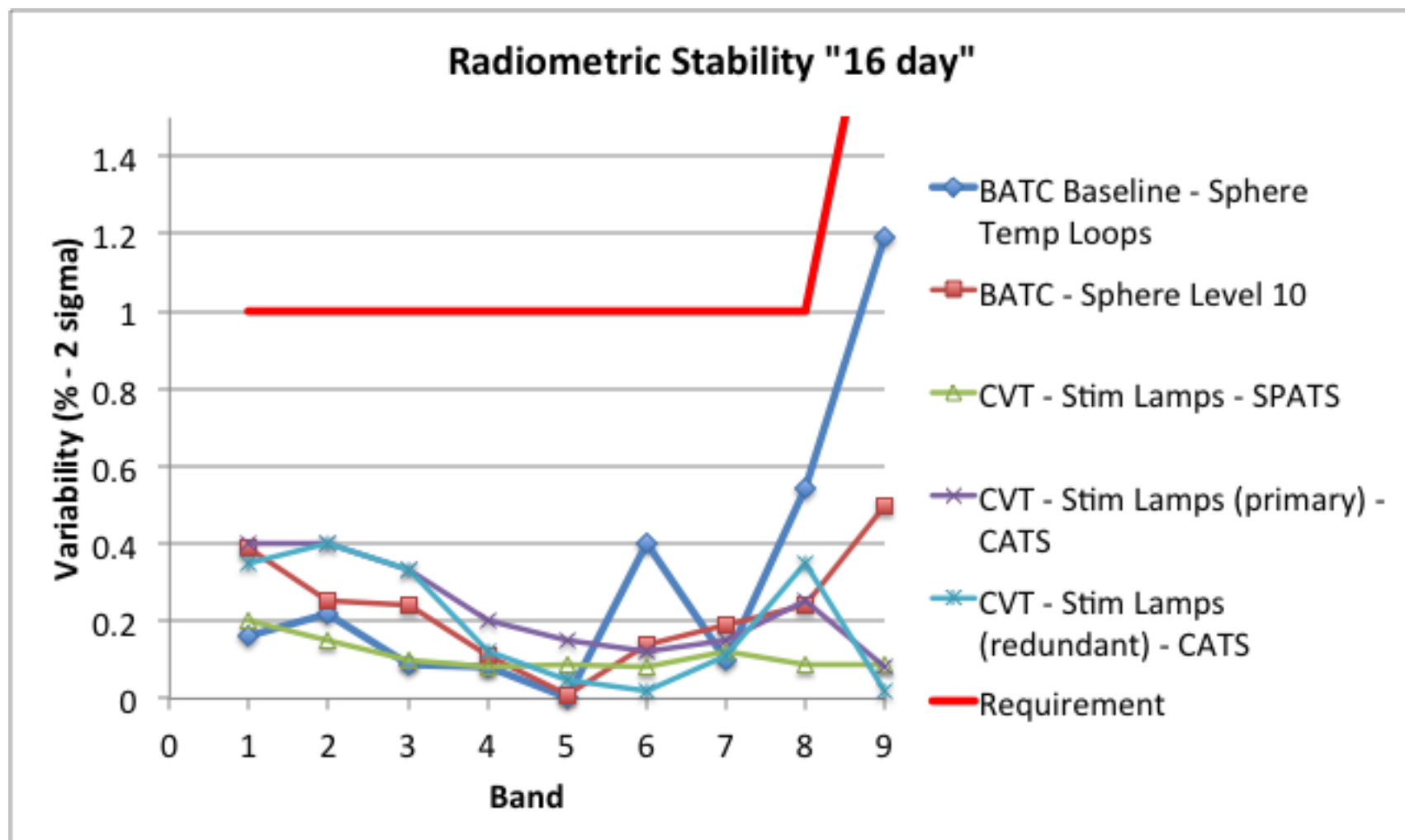




# Radiometric Performance - Stability



- Stability over 16 days (time between Solar Diffuser Cals) is excellent
  - $<0.54\%$   $2\sigma$  for all but Cirrus Band which is  $<1.19\%$







# Spatial Performance

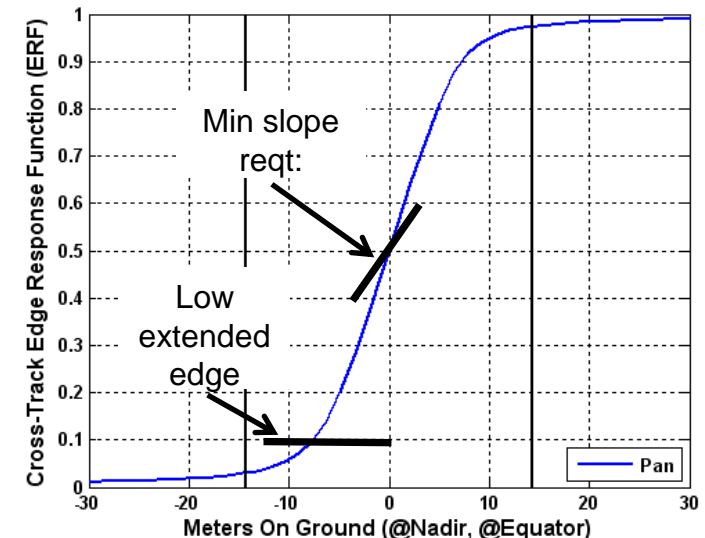
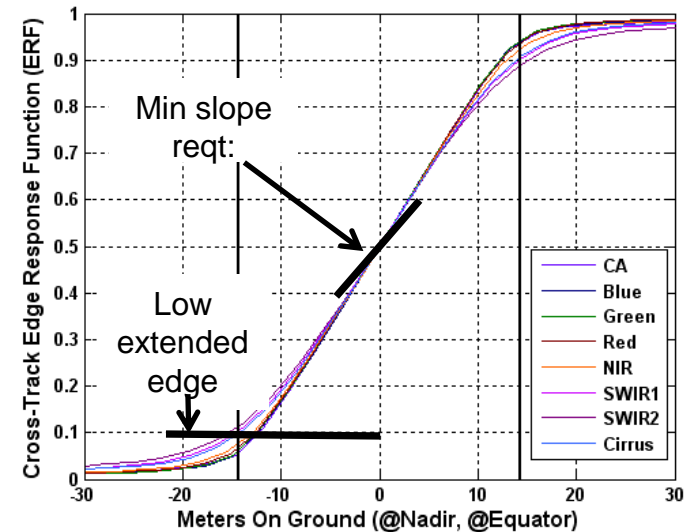


## ■ Spatial Performance

- Want sharp edges for change detection
- Measured spatial response has:
  - ❖ Steep slope (exceeding reqts)
  - ❖ Low extended edge (good half edge extent)
  - ❖ No ripple/overshoot

## ■ Geolocation

- Want good pointing knowledge, again for change detection
- Performance depends on both instrument and spacecraft; final measurements made during initial on-orbit checkout
- Pre-launch instrument measurements mapped line of sight of all detectors to reference pixel/boresight to  $\sim 1/10^{\text{th}}$  of a pixel
- On target to have absolute geometric accuracy of  $< 1/2$  pixel





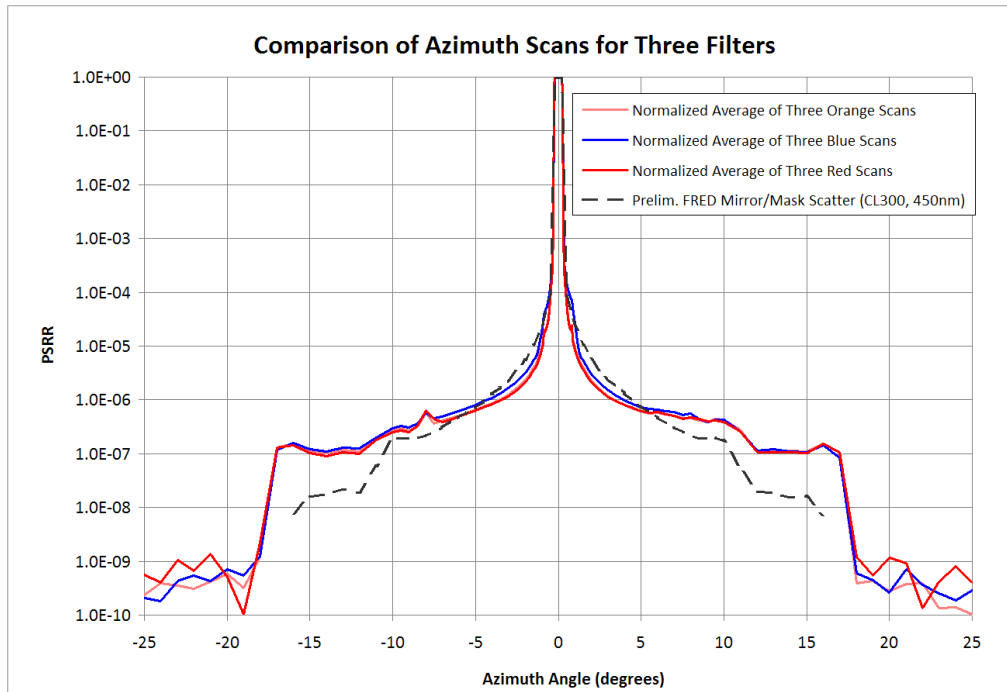
# OLI Stray Light Testing Complete



- Tests using BATC state-of-the-art stray light facility; had tremendous results
  - Background light from facility undetectable (detector noise dominated)
  - Reference point: 9 orders of magnitude is difference between 10:30 am sun and  $\frac{1}{4}$  moonlight



Stray Light Ninjas





# Summary



- OLI represents a generational change from ETM+ , but must preserve data continuity and therefore maintain solid calibration.
- Instrument design focuses on simplicity
  - Pushbroom vs. whiskbroom instrument
- Thorough pre-launch calibration and characterization complete
  - With unique BATC calibration facilities
- Performance meeting user needs



## Slides for Session Introduction



# Landsat Data Continuity Mission (LDCM) Overview

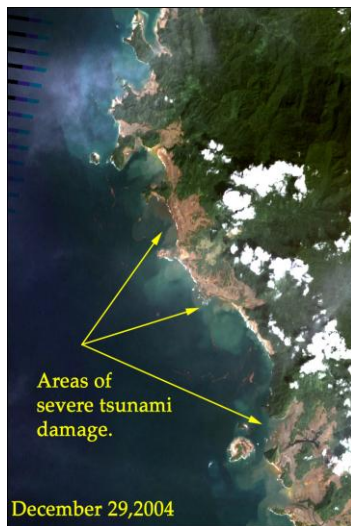


## *Mission Objectives*

- Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics
  - Land cover/use change
  - Human settlement and population
  - Ecosystem dynamics
  - Landscape scale carbon stocks
  - Resource management/societal needs

## *LDCM Data Needed to Address NASA Earth Science Focus Areas, Questions, and Applications*

<i>Focus Areas</i>	<i>Science Questions</i>
<ul style="list-style-type: none"> <li>• Carbon Cycle, Ecosystems, &amp; Biogeochemistry</li> <li>• Water &amp; Energy Cycle</li> <li>• Earth Surface &amp; Interior</li> </ul>	<ul style="list-style-type: none"> <li>- What are the changes in global land cover and land use, and what are their causes?</li> <li>- How do ecosystems, land cover &amp; biogeochemical cycle respond to and affect environmental change?</li> <li>- What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems ?</li> <li>- What are the consequences of increased human activities on coastal regions?</li> </ul>



## *Instruments*

- Operational Land Imager – BATC
- Thermal Infrared Sensor – GSFC

## *Spacecraft*

- Orbital

## *Mission Team*

- NASA Goddard Space Flight Center
- Dept. of Interior's United States Geological Survey (USGS)
- NASA Kennedy Space Center

Landsat 7 data used to aid Indonesian government with tsunami relief efforts (David Skole, Michigan State University)

**Launch Readiness Date – December 2012**

# LDCM Mission Overview



- **Mission Description**
  - 1 satellite
  - 5 year mission
    - ❖ 10 years of propellant
  - After declaration of operational readiness, responsibility for LDCM transitions to USGS
- **Orbit**
  - 705 km at equator
  - 98.2° Inclination Sun-Synchronous
  - 16-day ground repeat
  - 10am mean local time (descending node)
- **Spacecraft**
  - 3-axis stabilized
  - Instrument Accommodation
    - ❖ OLI
    - ❖ TIRS
- **Launch**
  - Launch Vehicle - Atlas V 401
  - Date: December 12, 2012



# Landsat and LDCM Spectral and Spatial Requirements

Landsat-5/7 TM/ETM+ Bands (μm)			LDCM Band Requirements (μm)		
			30 m Coastal/Aerosol	0.433 - 0.453	Band 1
Band 1	30 m Blue	0.450 - 0.515	30 m Blue	0.450 - 0.515	Band 2
Band 2	30 m Green	0.525 - 0.605	30 m Green	0.525 - 0.600	Band 3
Band 3	30 m Red	0.630 - 0.690	30 m Red	0.630 - 0.680	Band 4
Band 4	30 m Near-IR	0.775 - 0.900	30 m Near-IR	0.845 - 0.885	Band 5
Band 5	30 m SWIR-1	1.550 - 1.750	30 m SWIR-1	1.560 - 1.660	Band 6
Band 6	60/120m* LWIR	10.40 - 12.50	120 m LWIR-1	10.30 - 11.30	Band 10
			120 m LWIR-2	11.50 - 12.50	Band 11
Band 7	30 m SWIR-2	2.090 - 2.350	30 m SWIR-2	2.100 - 2.300	Band 7
Band 8**	15 m Pan	0.520 - 0.900	15 m Pan	0.500 - 0.680	Band 8
			30 m Cirrus	1.360 - 1.390	Band 9

OLI

TIRS

OLI

# Spotlight Session—LDCM

## **Preflight Calibration for the Thermal Infrared Sensor on the Landsat Data Continuity Mission**

**Kurtis Thome**, Dennis Reuter, Ramsey Smith—NASA/Goddard Space Flight Center; Allen Lunsford—Catholic University of America; Matthew Montanaro, Brian Wenny —Sigma Space Corporation; Zelalem Tesfaye—Bastion Technologies, Inc.

## **The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance**

### **Characterization**

**Brian Markham**—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee—Ball Aerospace & Technologies Corporation

### **Operational Land Imager: Radiometric Calibration Overview**

**Geir Kvaran**—Ball Aerospace & Technologies Corporation

### **Reflectance Factor Measurements of the OLI Flight Diffusers**

**Stuart Biggar**, Nikolaus Anderson—University of Arizona; Linda Fulton, Geir Kvaran, Harlan Kortmeyer—Ball Aerospace

### **The OLI Radiometric Scale Realization Round Robin Measurement Campaign**

**Hansford Cutlip**, Jerold Cole—Ball Aerospace & Technologies Corporation; B. Carol Johnson, Stephen Maxwell—NIST; Milton Hom, Brian Markham, Lawrence Ong—NASA Goddard Space Flight Center; Stuart Biggar—University of Arizona, College of Optical Sciences

## **Landsat Data Continuity Mission On-orbit Calibration and Validation Development**

**Ron Morfitt**, Esad Micijevic—Stinger Ghaffarian Technologies, Inc.; Brian Markham—NASA Goddard Space Flight Center

## **Calibration of Satellite Imagery, Recalibration of the Past, Through the Present, and into the Future Using Invariant Sites**

**David Aaron**, Larry Leigh—South Dakota State University; Nathan Leisso, Jeffrey Czapla-Myers—University of Arizona